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AUTHOR Morgan, Bruce B.: And Others
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ABSTRACT

A regression analysis was conducted of factors that help to explain the variance in physician distribution and which identify those factors that influence the maldistribution of physicians. Models were developed for different geographic areas to determine the most appropriate unit of analysis for the Western Missouri Area Health Education Center region. The data source was the area resource file (ARF) originally developed by the U.S. Bureau of Health Manpower. The subprogram REGRESSION from the Statistical Package for the Social Sciences was used in the analysis. Four models were developed comparing counties and Rand McNally Minor Trade Areas for the entire United States and for the four states comprising Federal Region VII. The four models explaining (or predicting) physician to population ratio allow for a cross-comparison between the county and trade areas unit of analysis at the regional and national level. It was found that more densely settled areas have more physicians and hospital beds but the ratio of physicians to population and hospital beds to population decreases with greater density. It is suggested that residual analysis based on trade areas would probably be more applicable to Missouri. A refined causal analysis model(s) can be of assistance to policy-makers, evaluators, and planners. A review of previous research is included. (SW)

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REGRESSION ANALYSIS OF PHYSICIAN DISTRIBUTION TO IDENTIFY AREAS OF NEED: SOME PRELIMINARY FINDINGS

By

Bruce B. Morgan, M.S., M.A.
Midwest Research Institute

Kenneth R. Mares, Ph.D.
Western Missouri Area Health Education Center

Cris R. Kukuk, Ph.D.
University of Missouri-Kansas City

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For

Western Missouri Area Health Education Center
University of Missouri-Kansas City Medical School
2220 Holmes
Kansas City, Missouri 64108

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INTRODUCTION

The health care needs of the individual are where efforts to improve the primary health care delivery system are often directed. The individual wants health care to be accessible within a reasonable time and distance, within the ability of the person to pay, and of an adequate quality to meet the person's health care needs. The individual also wants injurious environmental, occupational and personal health hazards to be known in order to take precautions.

Access to primary health care services is often expressed as a problem of maldistribution of physician manpower and an unequal distribution of physicians between urban and rural areas is emerging as a major issue for politicians and officials concerned with health manpower. Eisenberg and Cantwell (1976:459-460) reviewed almost two dozen public and private sector programs to address the problem of maldistribution or geographic imbalance of physician manpower.

The area health education centers (AHEC's) provide a set of programs to help alter the maldistribution of physicians and other health practitioners. AHEC's often provide residency training, continuing education, off-campus clinical education experience, and numerous support services in an attempt to address this problem. The Western Missouri Area Health Education Center (WMAHEC) is charged with similar responsibilities for a 38-county area in western Missouri.

As the AHEC program has matured, greater emphasis has been placed on accurately assessing health manpower needs in areas served and targeting programs to areas of greatest need ("underserved" area). The Department of Health, Education and Welfare (DHEW) has developed a variety of methods identifying areas of greatest health care needs. DHEW's methods have been used to identify "critical health manpower shortage areas", "medically underserved areas", and "high infant mortality areas". Most of these assessments are heavily dependent on physician/population ratios.

An attempt to define health care needs and what is "underserved" in terms of health manpower has been completed in part by the Office of Health Manpower Planning in Jefferson City, Missouri. However, no systemmatic analysis using the area resource file has been completed specifically for the WMAHEC region. One of the activities requested in the WMAHEC contract for October 1, 1977 to September 30, 1978 is to cooperate with planning agencies "to assess the health manpower needs of the area served by the AHEC program."

The purpose of this paper is to conduct a regression analysis of factors which will help explain the variance in physician distribution and consequently identify those factors that influence the maldistribution of physicians.

REVIEW OF PREVIOUS RESEARCH

A. Medically Underserved Areas

Confrey (1973:254) discussed the logic of a "shortage of health manpower " and pointed out the widespread use of the physician to population ratio where more complex estimations are lacking. DHEW (1975:8156) used the physician to population ratio as a major component in identifying critical health manpower areas.

In 1976, Morgan and McKim (1976:32) developed indicators of health status on 17 midwestern states to illustrate conditions and variations in health status. Several complications in developing quantitative health indicators to identify areas of deficiency were noted:

1. Indicators must account for differences in health status between areas.
2. Data on indicators must be available in a useful form.
3. Indicators must be suitable for a model to explain or predict health status.
4. Unit of analysis for data must be of sufficient size for indicator measurement (1976:34).

Morgan and McKim identified five characteristics of a good indicator: commonality, simplicity, adaptability, neutrality and utility, (1976:33).

B. Studies that Identify Factors Associated with Physician Location

Previous research has shown the maldistribution of physicians to be related to a variety of factors. Rushing and Wade (1973:283) noted that the uneven distribution of physicians was significantly associated with population size and urbanization, wealth of the population, and hospital facilities. Rushing and Wade (1973:285-289) regressed the physician to population ratio on median family income and population size-density. They found that the physician to population ratio increased as "community" wealth and population size-density increased. Rushing and Wade (1973:294) also found the distribution of physicians to be intertwined with a complex of demographic, social and economic factors.

Joroff and Navarro (1971:428) used a physician to population ratio to describe the adequacy of medical manpower and distribution. They noted the ratio was of little value at the regional and local level unless the components of the ratio are understood. In a multivariate analysis of the distribution of physicians in urban areas, they found the percent population 65 years and older as the best predictor of general practitioners and for specialities, median education of persons 25 years and medical facilities were the best predictors of distribution (1971:437).

Coleman (1976:19) analyzed what factors determined where physicians located. A physician to population ratio was used as a measure of physician availability and regressed against several variables to determine variance between counties. The current

distribution of physicians appears to be strongly associated with demand related variables: median family income, population density, median education of persons 25 years and older, and percent of population aged 65 years and over (1976:28). Outliers or residuals from the regression were subjected to detailed analysis to derive a smaller list of counties for programs to eliminate physician maldistribution (1976:22).

C. Service Areas as Unit of Analysis

The previous studies discussed in this paper have tended to use the county as the unit of analysis. Morgan and McKim (1976:40) found several limitations in the use of the county as a unit of analysis. The limitations included: health resources are not evenly distributed by county, the highway network may mean health resources are accessible in an adjoining county even though not in county analyzed, and trade areas serve as geographic unit for services other than health care. Morgan and McKim's indicators of health status could only explain 33 percent of the variance between counties as the unit of analysis, but using trade areas, the indicators explained almost 70 percent of the variance.

Denney (1972:6-10) described several general principles in delineating service areas. For any given service, Denney said there was an optimum condition at which the population of a community would support that service. As population density increased, the distances between points of similar service decreased. Ideal service areas would maximize population at central points and minimize distance from the center to the edge of the service area.

In regard to health care services, Denney (1972:64-73) stated primary care should be located on a 16 to 32 mile pattern within 20 to 30 minutes travel time. Denney's primary work was in the midwest and applied to nonmetropolitian areas. In metropolitian areas, the same general principles would apply but the distance would be less between primary health care centers.

Secondary areas in Denney's framework would be on a one-hour time distance pattern. Primary health care areas* (PHCA's) in Missouri were identified in 1974 as locations for primary care and secondary care facilities. PHCA's were verified by health planners and a random survey of health consumers in each area. PHCA's have been used in Missouri as one geographic unit of analysis for health manpower studies.**

* A primary health care area is composed of one or more counties clustered around a particular town or trade center. The trade center is the largest community in the area and is increasing in size. The driving time from any point in the area to the trade center is no more than one hour, at or below 55 m.p.h. These trade centers are characterized as towns having diverse shopping facilities, usually daily papers and AM radio stations, primary medical facilities, and vocational (and in some cases higher) educational facilities.

**Lanis Hicks, Lyn Fox, and Gayle Lane, Missouri Health Manpower Analyses: Summaries, Conclusions, Recommendations. Jefferson City, Missouri: Missouri Department of Social Services Office of Comprehensive Health Planning, June 1976.

METHODOLOGY

This section describes the framework used in this study, data sources, unit of analysis, and analytical techniques used.

A. Framework Used in Study

Table 1 contains a list of variables used in the regression analysis of physician distribution. This list was derived from previous research which found one or more of the variables as significant predictors of physician location. The focus of this regression analysis was to develop a model that explained the greatest variance between areas and to use the model to identify areas of greatest need so WMAHEC policymakers could better target their programs. Models were developed for different geographic areas to determine the most appropriate unit of analysis for the WMAHEC region.

A physician to population ratio was used as the dependent variable and a set of independent variables were analyzed to determine both bivariate and multivariate relationships between the variables. Number of physicians, a hospital bed to population ratio, and a hospital expenditures to population ratio were used to represent the "medical environment." Previous research, cited in the previous section, has shown physicians tend to move to areas where there are other physicians, specialists and medical facilities.

TABLE 1

LIST OF VARIABLES USED IN ANALYSIS

DOCS	-	Number of Physicians (MD's, 1970 and DO's 1971)
BEDR	-	Number of Hospital Beds, 1968 - Population Ratio
HOSP$R	-	Hospital Expenditures, 1974 - Population Ratio
OVER65R	-	Percent 65 years and older, 1970 - Population Ratio
AFDCR	-	Percent Families Receiving Aid to Families with Dependent Children Public Assistance, 1970 - Population Ratio
FEMHEADR	-	Percent Families with Female Head, 1970 - Population Ratio
EDUC	-	Median Education of Population 25 years and older, 1970
INCOME	-	Per Capita Income, 1970
POP	-	Total Population of Area, 1970
DENSITY	-	Population Density (Total Population/Land Area)

Socioeconomic and education variables have also been significant in previous research on physician location. The previous research of Grimes, Lee, Lefko, and Hemphill (1977:771-773), Heald, Cooper, and Coleman (1974:27) and Diseker and Chappell (1976:559-563) indicates the importance that socioeconomic and education variables have on physician location. The following variables were selected which previous research has shown to be the most significant such as: percent population 65 years and older to total population ratio, percent families receiving aid to families with dependent

children to population ratio, percent families with female head to population ratio, median education of population 25 years and older, and per capita income of families and unrelated individuals.

Size and density have also been significant in previous research. In this study, total population of the area and population density were used. Larger and densely settled areas have tended to attract a larger number physicians than smaller, less densely settled areas.

This study, unlike previous research, has used these variables in regression models on different geographic units of analysis.

B. Data Sources

The data source for this study was the area resource file (ARF) originally developed by the Bureau of Health Manpower, Health Resources Administration, Department of Health, Education and Welfare. The ARF is a computer-based, county-specific health information system containing population characteristics, economic, health manpower, health facility, utilization, and health status data. ARF was originally developed as a tool to assist in the location of AHEC's and as a general purpose area data file. The ARF file contains over 500 variables on 3,078 counties, and up to the 1976 version used in this study was continually updated.

C. Unit of Analysis

Studies cited in the brief review of previous research have used cities, counties, states and multistate regions as the unit of analysis. This study was primarily concerned with the development of a regression model which relates to the physician

to population ratio in order to aid WMAHEC administration and evaluation staff to better identify areas of greatest need in their target region. Morgan and McKim's work, previously cited, found the trade area a preferable unit of analysis over counties when trying to explain variance between areas on the indicators of health states. Since their work covered 17 states in the midwest, this study attempted to replicate the county and trade area as a unit of analysis for the entire United States (3,078 counties). The WMAHEC area is located in Federal Region VII, so this area was also used to replicate the county and trade area as a unit of analysis. Figure 1 illustrates the WMAHEC region and Figure 2, Federal Region VII.

Rand McNally Minor Trade areas were used as the trade area unit of analysis for the United States and Federal Region VII. Rand McNally Minor Trade areas were used because they were available for the entire United States, were an acceptable trade area used in business and industry, and were available on the ARF file. Other trade area designations, such as Denney's primary health care areas in Figure 3, were not available for the entire county. A separate regression analysis was conducted on the State of Missouri using counties, Denney's primary health care areas, and Rand McNally Minor Trade areas. Rand McNally Minor Trade areas are too large to accurately represent primary health care service areas, but more closely resemble trade areas for secondary and tertiary care services. For purposes of illustration in this study, the Rand McNally areas were used since they do cover the entire county and have some acceptance in business and government.

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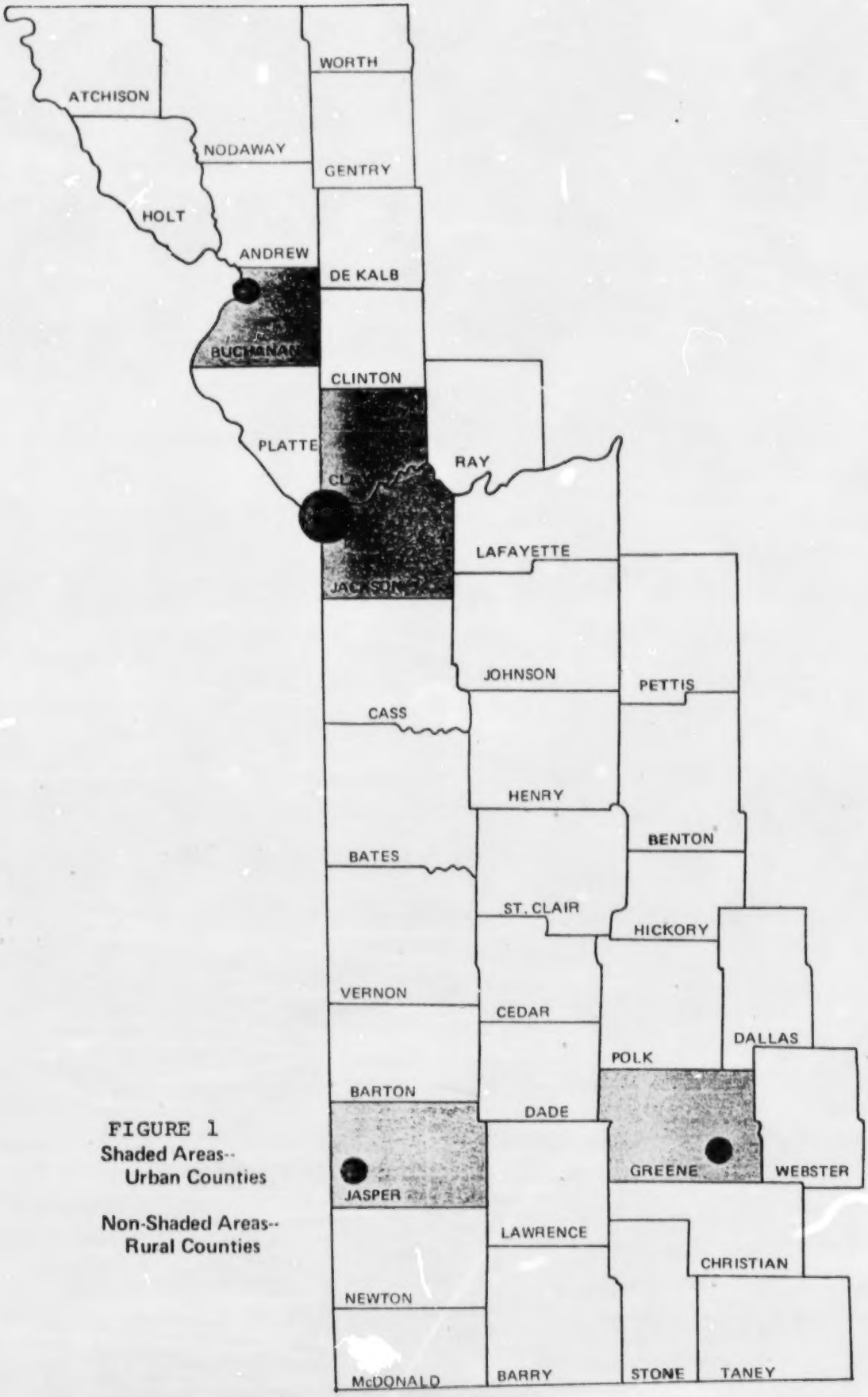

FIGURE 1
Shaded Areas--
Urban Counties

Non-Shaded Areas--
Rural Counties

REGION VII
HEALTH SERVICE AREAS
P.L. 93-641
NATIONAL HEALTH PLANNING AND RESOURCE DEVELOPMENT ACT

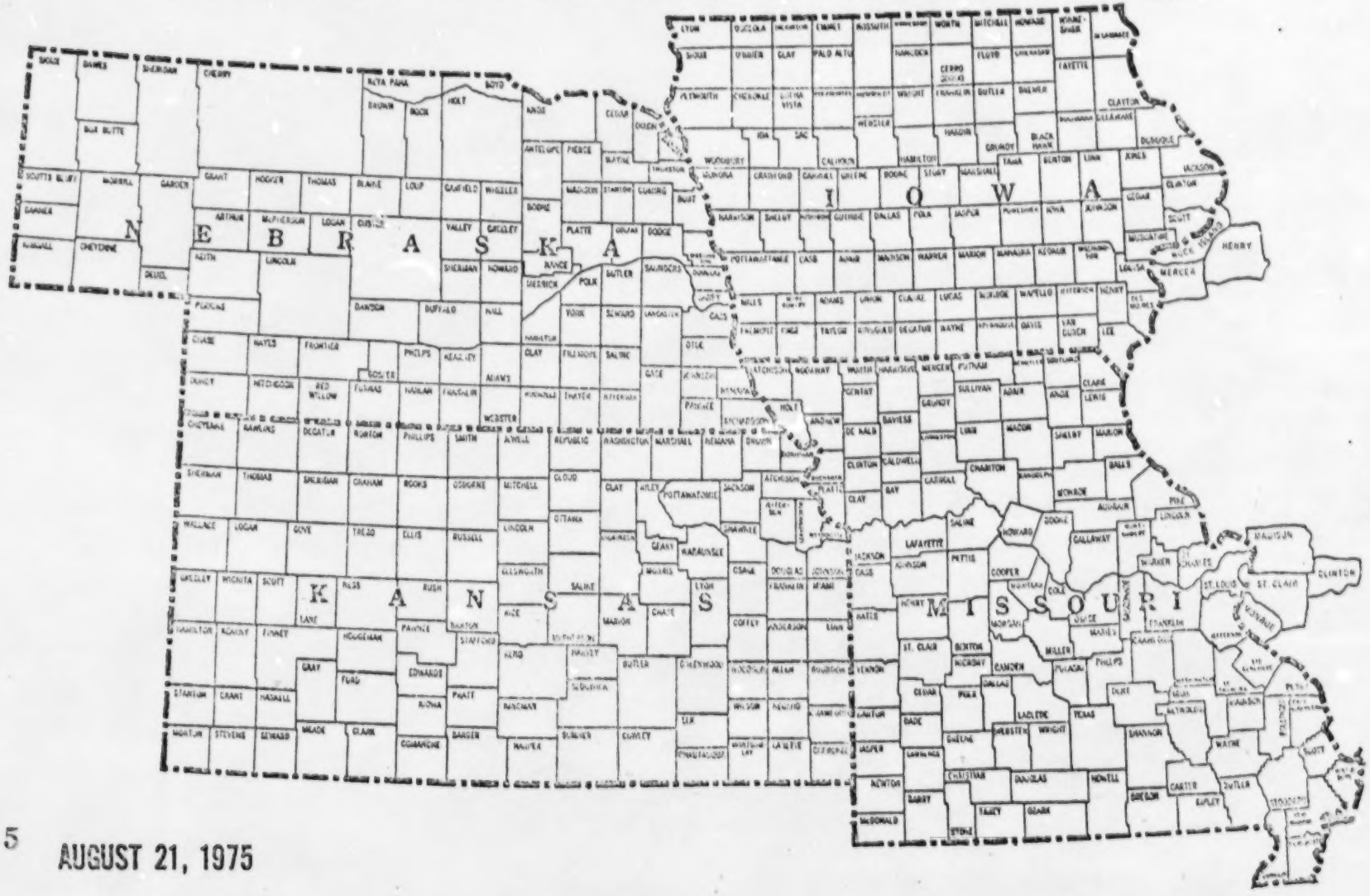

FIGURE 2

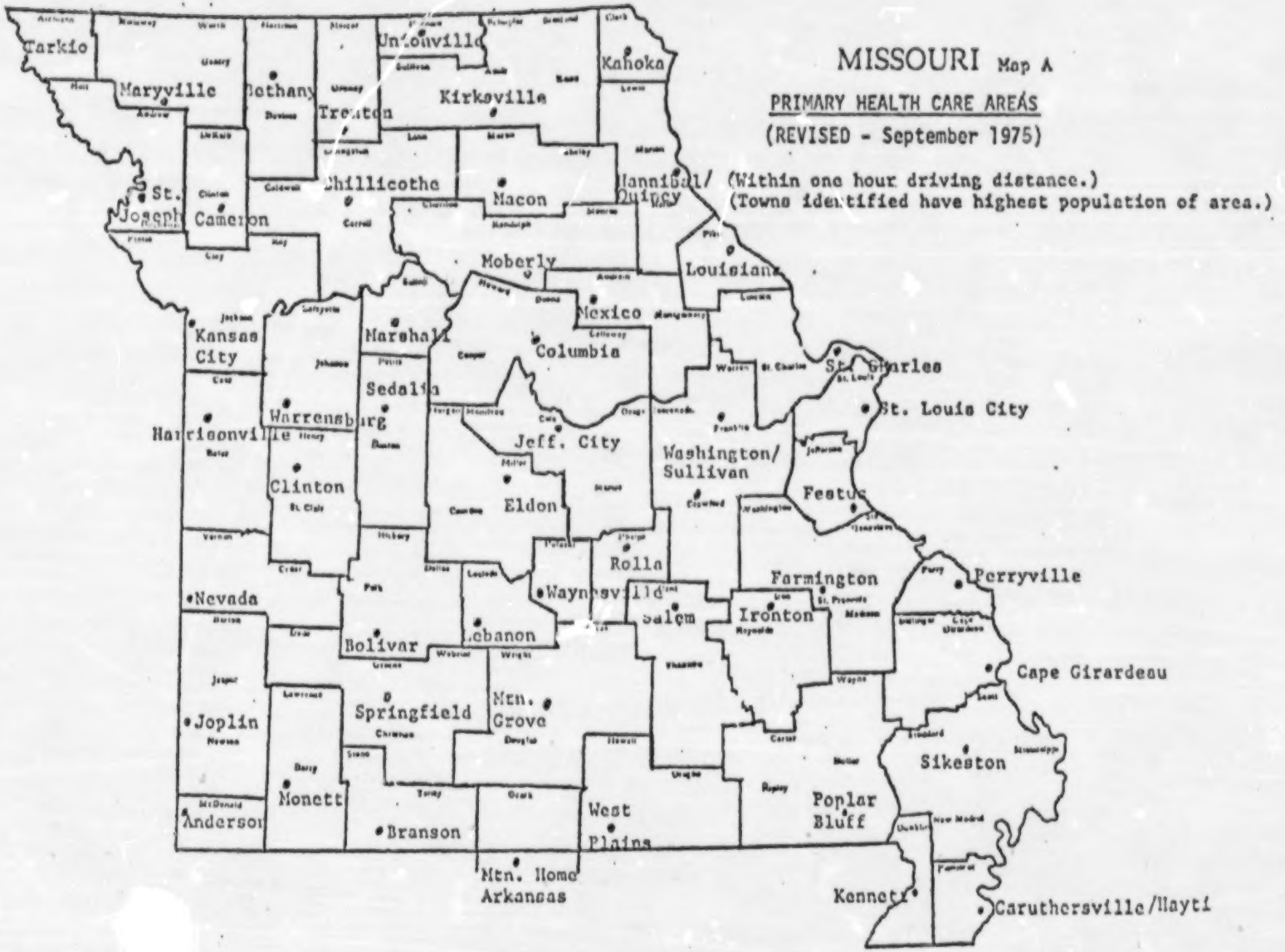

FIGURE 3

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D. Analysis

Multiple regression analysis was the general statistical technique used in this study to analyze the relationship between the physician to population ratio dependent variable and the independent or predictor variables. Multiple regression was used as a descriptive tool to identify those variables which were significant predictors of the physician to population ratio in both bivariate and multivariate relationships. The subprogram REGRESSION from the Statistical Package for the Social Sciences was used in the analysis.

FINDINGS

A. Causal Analysis Comparing Counties and Trade Areas in United States and Federal Region VII

Four models were developed comparing counties and Rand McNally Minor Trade Areas for the entire United States and for the four states comprising Federal Region VII. These four models explaining (or predicting) physician to population ratio allow for a cross comparison between the county and trade area unit of analysis at the regional and national level. Counties in the mid-west are somewhat smaller in geographic size than the western United States and have lower population densities than counties in the heavily populated eastern United States.

1. Bivariate Analysis: Table 2 illustrates the bivariate correlation coefficients (simple r's) of the independent variables and the significance at the .05 level. At the county unit of analysis, HOSP$R, OVER65R, EDUC and INCOME are significant when regressing each with physician to population ratios for all counties in the United States. BEDR, OVER65R, EDUC and INCOME are significant in the bivariate relationship for counties in Federal Region VII.

At the Rand McNally Minor Trade Area units of analysis, HOSP$R, OVER65R and EDUC are significant bivariate predictors for all Rand McNally Minor Trade Areas in the United States. Only BEDR is significant in the bivariate relationship with physician to population ratio for Rand McNally Minor Trade Areas in Federal Region VII. This regional difference between trade ares in Federal Region VII and the United States might be partially

TABLE 2

BIVARIATE CORRELATION COEFFICIENTS BETWEEN DEPENDENT VARIABLE, PHYSICIAN TO POPULATION RATIO, AND INDEPENDENT VARIABLES

	UNIT OF ANALYSIS			
	Rand McNally Trade Areas		Counties	
Variables	United States	Region VII	United States	Region VII
DOCS	.0082	-.0373	.0111	.0108
BEDR	-.0775	-.2926*	-.0252	-.1743*
HOSP$R	.0945*	.0692	.0513*	.0708
OVER65R	.2102*	.2758	.1759*	.1486*
AFDCR	-.0450	.0741	-.0153	.0636
FEMHEADR	.0063	.1242	-.0189	-.0595
EDUC	.1028*	-.1715	.1157*	-.1834*
INCOME	.0571	-.1611	.0720*	-.1170*
POP	.0044	-.0553	.0093	-.0138
DENSITY	.0369	-.0873	-.0014	-.0029
N	491	48	3078	417

* Statistically significant at .05 level.

accounted for by several factors: trade areas in Region VII are smaller in terms of population than those in other parts of the country; a high number of hospital beds to population in Region VII; or the small N of trade areas in Region VII requires a high

correlation coefficient to be significant while the larger N of trade areas in the United States allows a lower coefficient to be significant.

2. Multivariate Analysis: Table 3 contains the results from four multivariate models predicting physician to population ration comparing counties and trade areas for the United States and Federal Region VII. Only those independent variables significant at the .05 level in each model are reported. BEDR, HOSP$R, and OVER65R were significant predictors of physician to population ratio in all four models. The number of beds and hospital expenditures which are considered a measure of the availability of hospital facilities as a primary consideration of physician location is consistent with the studies of Martin (1968), Parker et al. (1969), and Navarro (1974.) EDUC was a significant predictor variable in all models except the trade area model for Federal Region VII in which FEMHEADR was a significant predictor variable.

In all four models, the BEDR Beta coefficient is negative. This coefficient implies that as the numberof hospital beds to population increases, the ratio of physicians to population decreases. This finding seems contrary to previous research on physician location except when the variables are analyzed in greater detail. The physicians to population ratio was used as the dependent variable and DOCS represented the number of physicians. The bivariate relationship between the number of physicians and population density is positive. However, as shown in Table 2, the bivariate relationship between the physicians to population ratio

and density is negative. The same relationship exists when comparing number of hospital beds with density and the ratio of hospital beds to population with density. Thus, more densely settled areas have more physicians and hospital beds but the ratio of physicians to population and hospital beds to population decreases with greater density.

TABLE 3

BETA COEFFICIENTS FOR INDEPENDENT VARIABLES PREDICTING PHYSICIAN TO POPULATION RATIO IN EACH CAUSAL MODEL AT .05 LEVEL OF SIGNIFICANCE FOR RAND MCNALLY MINOR TRADE AREAS AND COUNTIES IN UNITED STATES AND FEDERAL REGION VII

	UNIT OF ANALYSIS			
	Rand McNally Trade Areas		Counties	
Variables	United States	Region VII	United States	Region VII
DOCS				
BEDR	-.1758	-1.1563	-.1647	-.3531
HOSP$R	.3420	1.1867	.1279	.3610
OVER65R	.2778	.3310	.2163	.1815
AFDCR				
FEMHEADR		.3008		
EDUC	.1005		.1353	-.1186
INCOME				
POP				
DENSITY				
R^2	.11	.55	.06	.14
N	491	48	3078	417

Beta coefficients for HOSP$R, OVER65R, and FEMHEADR are positive in the four models as would be expected. The Beta coefficients for EDUC are positive for the trade area and county models for the United States but negative in the county model for Federal Region VII. In Federal Region VII, this relationship indicates that the lower the median education level, the higher

is the ratio of physicians to population. This finding varies from previous physician location research cited earlier. The bivariate relationship between median education and the number of physicians is weakly positive.

The proportion of variance explained between areas on the physician to population ratio is represented for each model in Table 3 by R^2 . The trade area models for both the United States and Federal Region VII explain a higher proportion of variance (55 percent) of the four models. The trade area model in Federal Region VII appears to be the best model to explain variance between areas on the physician to population ratio. The trade areas, based on Rand McNally Minor Trade Areas, are too large for primary health care area but more applicable to secondary and tertiary health care areas. The next section discusses an alternative trade area model for the State of Missouri.

3. Analysis of Outliers or Residuals: The results from the four models presented above can be used to predict the value of the physician to population ratio for each individual unit of analysis. The difference between the predicted value and actual value for a unit (county or trade area) is referred to as the residual. A confidence interval can be established for the line of predicted values to include actual values within one or two standard deviations above and below the line of predicted values. Those counties or trade areas outside this confidence interval can be subjected to further analysis as outliers.

The analysis of residuals or outliers was a significant portion of a recent study of physician location by Coleman (1976). Coleman (1976:17) described negative outliers (areas with fewer physicians to population than predicted) were areas which may have a shortage of physicians. Outliers that are on the positive side (more physicians to population than predicted) were identified as possible sources for recruiting physicians for areas with severe maldistribution problems. Coleman (1976:viii) found more counties with low outliers in the north central region (includes Missouri) than for other parts of the country.

Coleman (1976:86-87) listed 39 counties in Missouri as low outliers. Residuals from the models identified in Table 3 for counties in Federal Region VII and the United States were compared with Coleman's study. In the county model for Federal Region VII, only 12 counties identified as low outliers matched the 45 identified by Coleman. The county model for Federal Region VII explained 14 percent variance between counties while the Coleman model predicted 12 percent variance for general practioners, 56 percent for other primary care physicians, and 67 percent for non-primary care physicians. Coleman's analysis of outliers explained 18 percent variance for general practitioners, 67 percent for other primary care physicians, and 44 percent for non-primary care physicians (1976:28). Coleman's analysis identified a larger number of outliers in Missouri because he compared those counties against all counties in the United States; this study only compared the counties with Federal Region VII.

Missouri counties that are outliers in Coleman's study fare better when compared with Region VII counties.

Residual analysis based on trade areas would probably be more applicable to Missouri since the trade area model for Region VII explained the most variance between areas in the region. The 5 Rand McNally Minor Trade Areas in the WMAHEC area show only minor differences from the predicted values. The physician to population ratios for Rand McNally Minor Trade Areas in the WMAHEC area appear not to be severe shortage areas when compared to Region VII. If the Coleman study were replicated by trade area, it would probably show the WMAHEC area below the national physician to population ratio.

Only 9 of the 38 WMAHEC counties are negative outliers using the county model for Region VII (see Figure 4). Again, when compared to all counties in the country, a greater number of counties would be low outliers in Missouri and the WMAHEC area. This finding was confirmed in research by Morgan and McKim (1976: 35-38) on indicators of health status for 1559 counties in 17 midwestern states.

Residual analysis is an important tool to use to identify areas of medical underservice or shortage of physicians. Assuming the regression models of physician distribution presented in this study could be refined, residual analysis would help identify those counties and trade areas to target AHEC programs. If an area is significantly higher than predicted, less program emphasis should be placed there if the goal of AHEC's is to serve areas of physician shortage.

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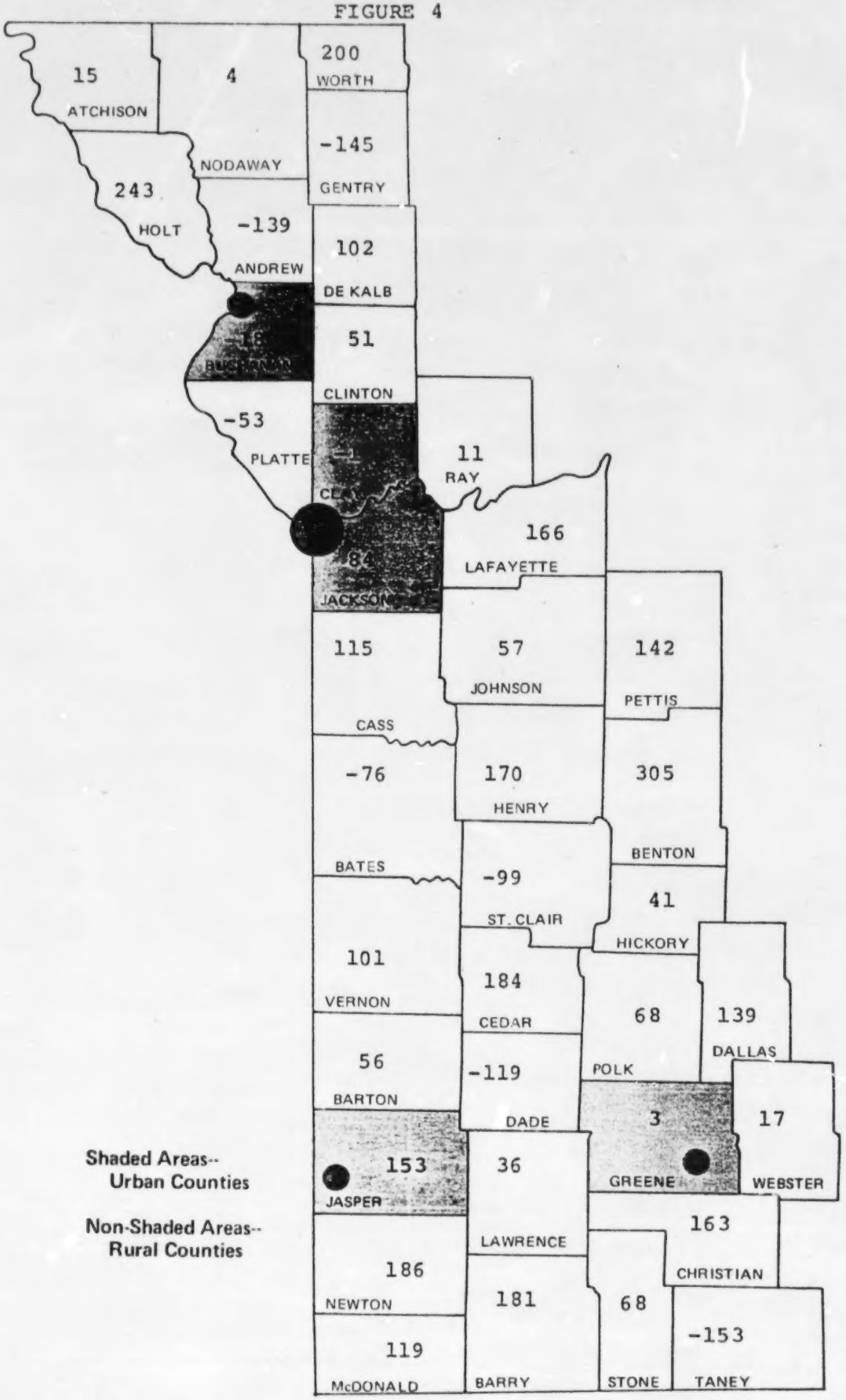
FIGURE 4



Shaded Areas--
Urban Counties

Non-Shaded Areas--
Rural Counties

B. Causal Analysis Comparing Counties, Primary Health Care Areas, and Trade Areas in Missouri

Table 4 presents three models developed within the State of Missouri comparing counties, primary health care areas, and Rand McNally Minor Trade Areas. Beta coefficients that are significant at the .05 level presented for each regression model. Physician to population ratio was again the dependent variable.

The models for Missouri are different from those for Federal Region VII and the United States. The counties model for Missouri explains 74 percent of the variance in physician to population ratio (compared to 14 percent for Region VII and 6 percent for the United States). Four variables are significant: HOSP$R, DOCS, POP, and EDUC. DOCS and POP were significant in the Region VII or United States models.

The primary health care area, based on Denney's delineation method, explains 83 percent of the variance in the physician to population ratio with five variables: HOSP$R, DOCS, POP, DENSITY, and FEMHEADR. The Rand McNally Minor Trade Area model explains 89 percent variance between areas with two variables. HOSP$R and AFDCR compared to 11 percent for the United States and 55 percent for Region VII. The primary health care area, though going up some explained variance, is the most appropriate trade area model for Missouri.

TABLE 4

BETA COEFFICIENTS FOR INDEPENDENT VARIABLES PREDICTING PHYSICIAN TO POPULATION RATIO IN EACH CAUSAL MODEL AT .05 LEVEL OF SIGNIFICANCE FOR RAND MCNALLY MINOR TRADE AREAS, PRIMARY HEALTH CARE AREAS, AND COUNTIES IN THE STATE OF MISSOURI

	UNIT OF ANALYSIS		
Variables	Rand McNally Minor Trade Area	Primary Health Care Area	Counties
HOSP$R	.880	.211	.564
DOCS	0	6.199	.950
POP	0	-3.846	-.557
EDUC	0	0	.114
DENSITY	0	-2.120	0
FEMHEADR	0	- .273	0
AFDCR	-.279	0	0
R	.887	.826	.735
N	15	50	115

The counties model for Missouri explains greater variance between areas than comparable county models presented for Region VII and the United States. This is partially explained by two major factors: large amount of hospital expenditures in recent years and large number of physicians due to medical schools and centers. In recent years, several new and renovated hospital facilities have been completed across Missouri. The state contains six medical schools (4 for MD's and 2 for DO's). The presence of medical schools and major medical centers in the state's metropolitan areas account for a large number of physicians.

CONCLUSIONS

This paper has demonstrated a technique of regression analysis of physician distribution to identify areas of need. A refined causal analysis model(s) can assist WMAHEC policy-makers, evaluators and planners to better target resources towards physician shortage areas.

Trade areas similar to Denney's primary health care areas should be developed and used as the unit of analysis. County data is useful but of less value in explaining variance between areas. Since people seek and utilize health services on a trade area rather than a county basis, trade areas should be used to better reflect areas of need.

The variables used in these preliminary models could be refined, additions made, and others substituted which are subject to AHEC program influence. Program planning and development to address maldistribution of physicians and other health practitioners can be made more effective when such models are used in the decision making process.

The ARF is an excellent data base to begin with for additional data. Models could also be developed for general practitioners, other primary care physicians, and speciality groups.

The tools of analysis are available and with additional refinements, WMAHEC can have a useful model of determining physician shortage areas to target resources, match needs of areas with available programs, and have a baseline for evaluative purposes in longitudinal evaluations of WMAHEC programs.

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